



Water Hammer at San Onofre

Section 7.3

What is Water Hammer?

A pressure transient which creates fluid shock waves in piping systems due to changes in fluid velocity or pressure.



Learning Objective 1

Describe three types of water hammer and their causes.

Learning Objective 2

Describe corrective actions that were taken to prevent previous steam generator water hammer problems.

Learning Objective 3

Describe the damage caused by the water hammer event at San Onofre Nuclear Generating Station Unit 1 (SONGS-1).

Learning Objective 4

Describe how multiple check valve failures contributed to the initiation of the water hammer at SONGS-1.

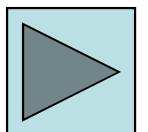
Learning Objective 5

Discuss how check valve testing required by the American Society of Mechanical Engineers Boiler and Pressure Vessel code could have prevented the SONGS-1 water hammer incident.

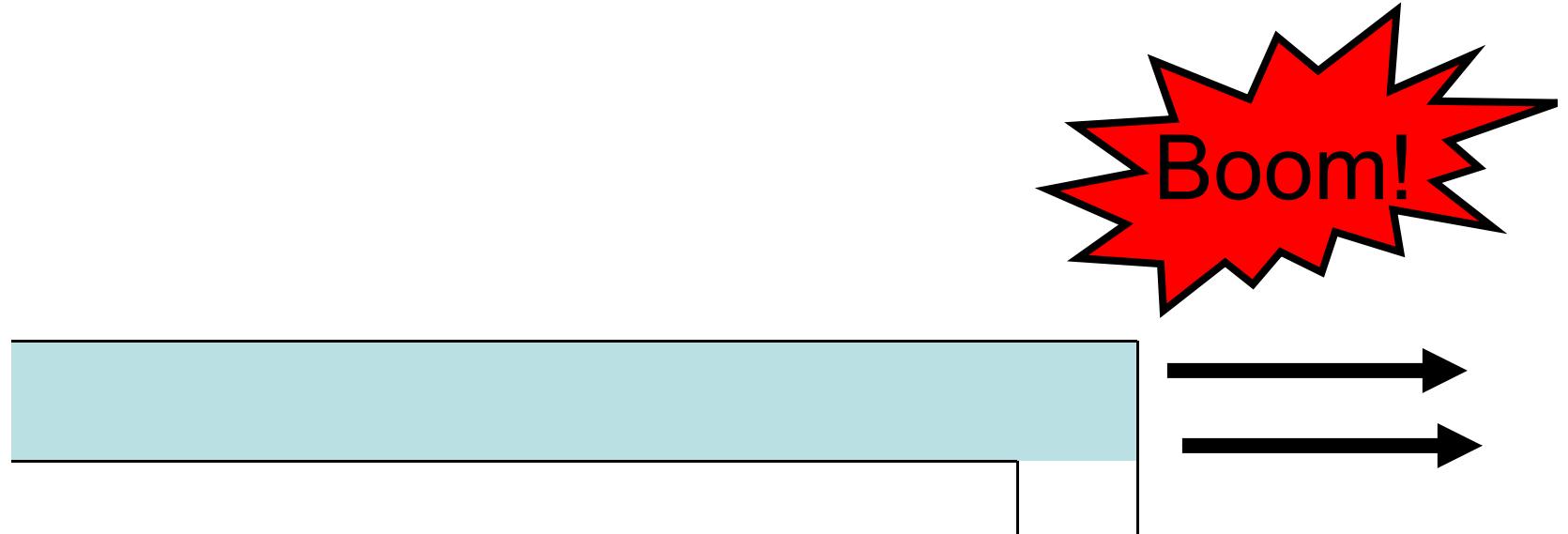
Types of Water Hammer

(Section 7.3.2)

- Classical water hammer
- Condensation induced water hammer
- Steam Generator water hammer

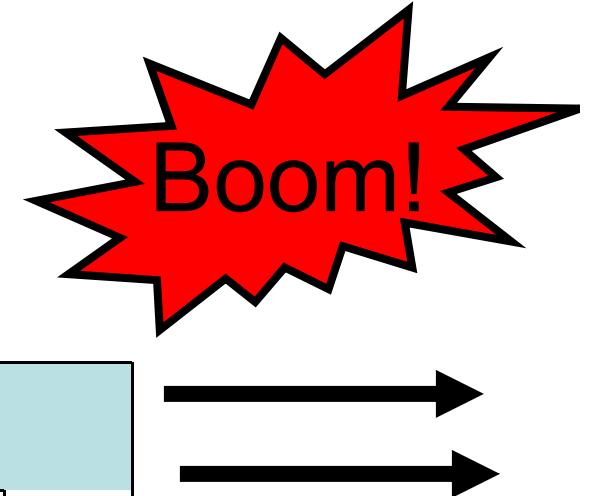


Classical Water Hammer



- ❖ Generally a shock wave created by a moving fluid column suddenly stopping. Usually accompanied by noise.

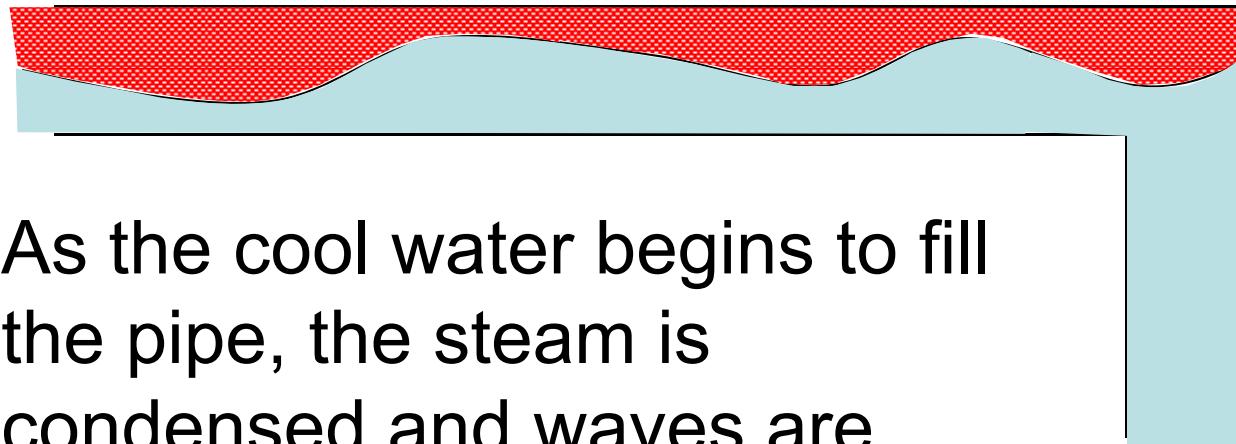
Classical Water Hammer - Common Causes



- ❖ Failure to properly fill and vent system before establishing flow.
- ❖ Sudden valve closure.

Condensation-induced Water Hammer

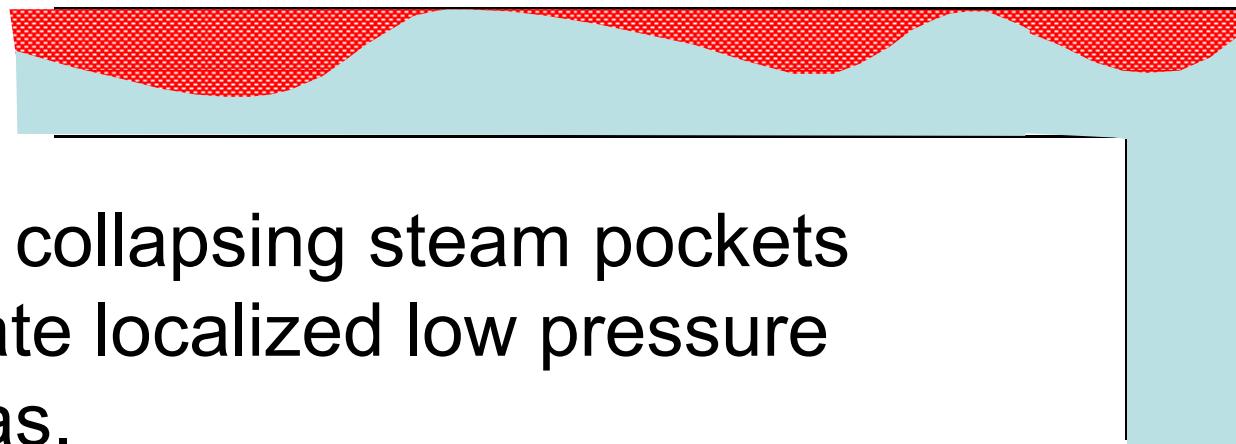
- ❖ Begins w/ a long horizontal steam filled pipe being filled by relatively cool water (AFW).



- ❖ As the cool water begins to fill the pipe, the steam is condensed and waves are formed.

Condensation-induced Water Hammer

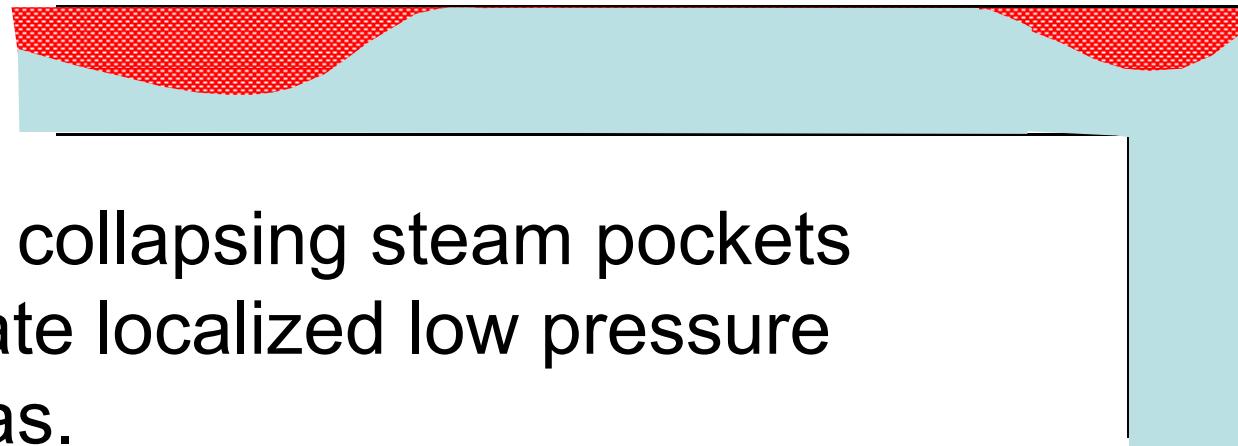
As the water level & waves increase, a volume of steam can be trapped, where it will condense rapidly.



The collapsing steam pockets create localized low pressure areas.

Slugs of water accelerate towards the low pressure areas.

Condensation-induced Water Hammer



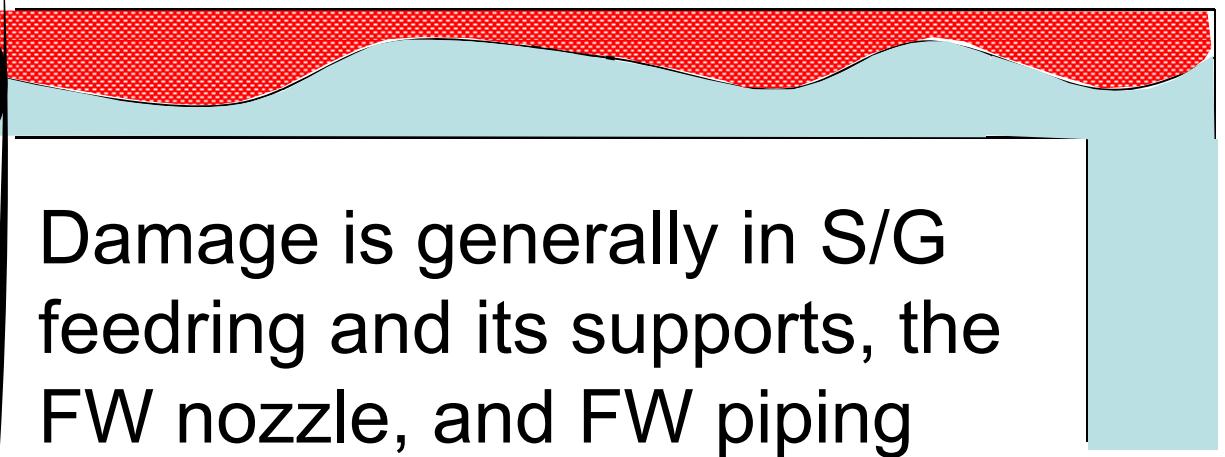
The collapsing steam pockets create localized low pressure areas.

Slugs of water accelerate towards the low pressure areas.

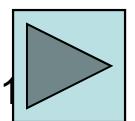


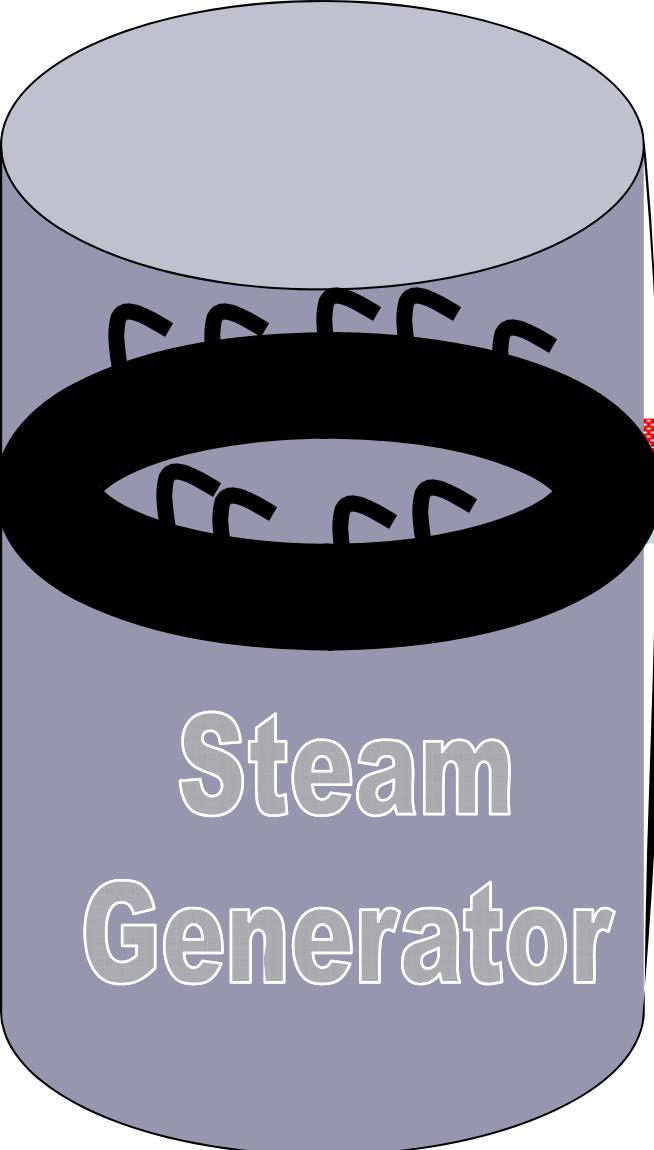
S/G Water Hammer is condensation-induced water hammer in a feedwater line.

Causes are generally the



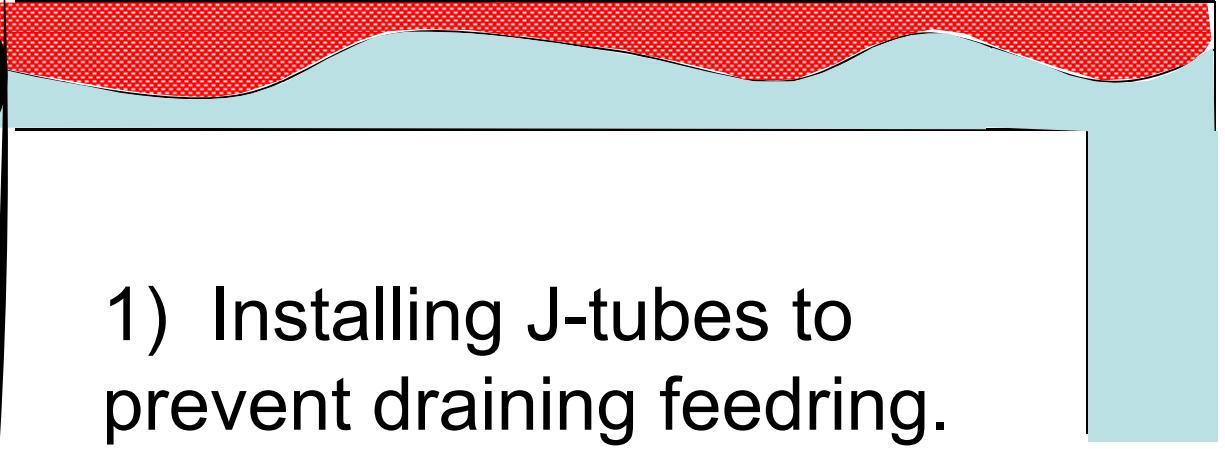
Damage is generally in S/G feeding and its supports, the FW nozzle, and FW piping snubbers & supports.





3 Modifications to prevent water hammer.

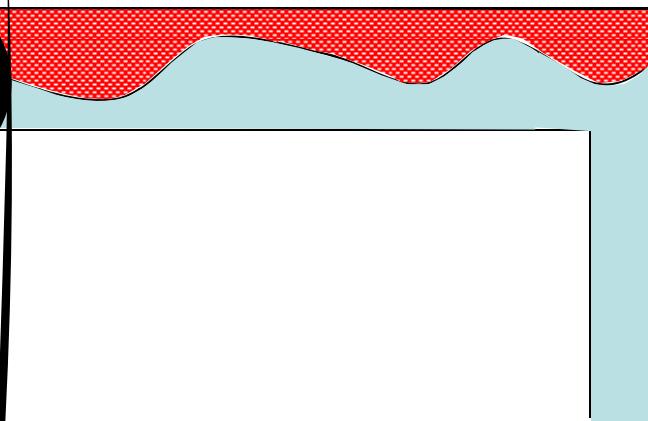
(Section 7.3.1)

- 
- 1) Installing J-tubes to prevent draining feeding.

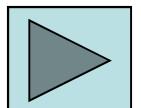
3 Modifications to prevent water hammer.

(continued)

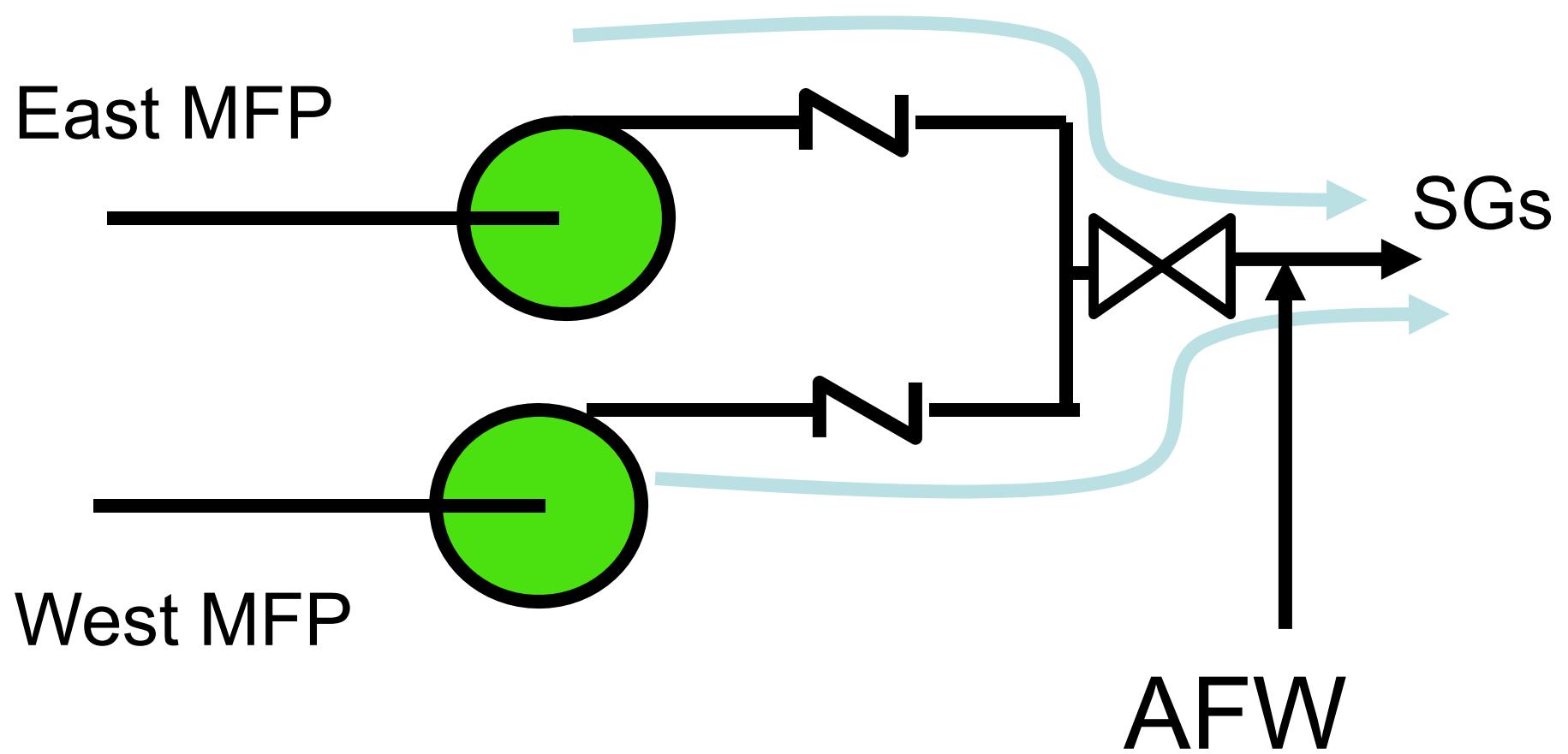
- 2) Shorten Horizontal runs of FW piping adjacent to S/Gs.



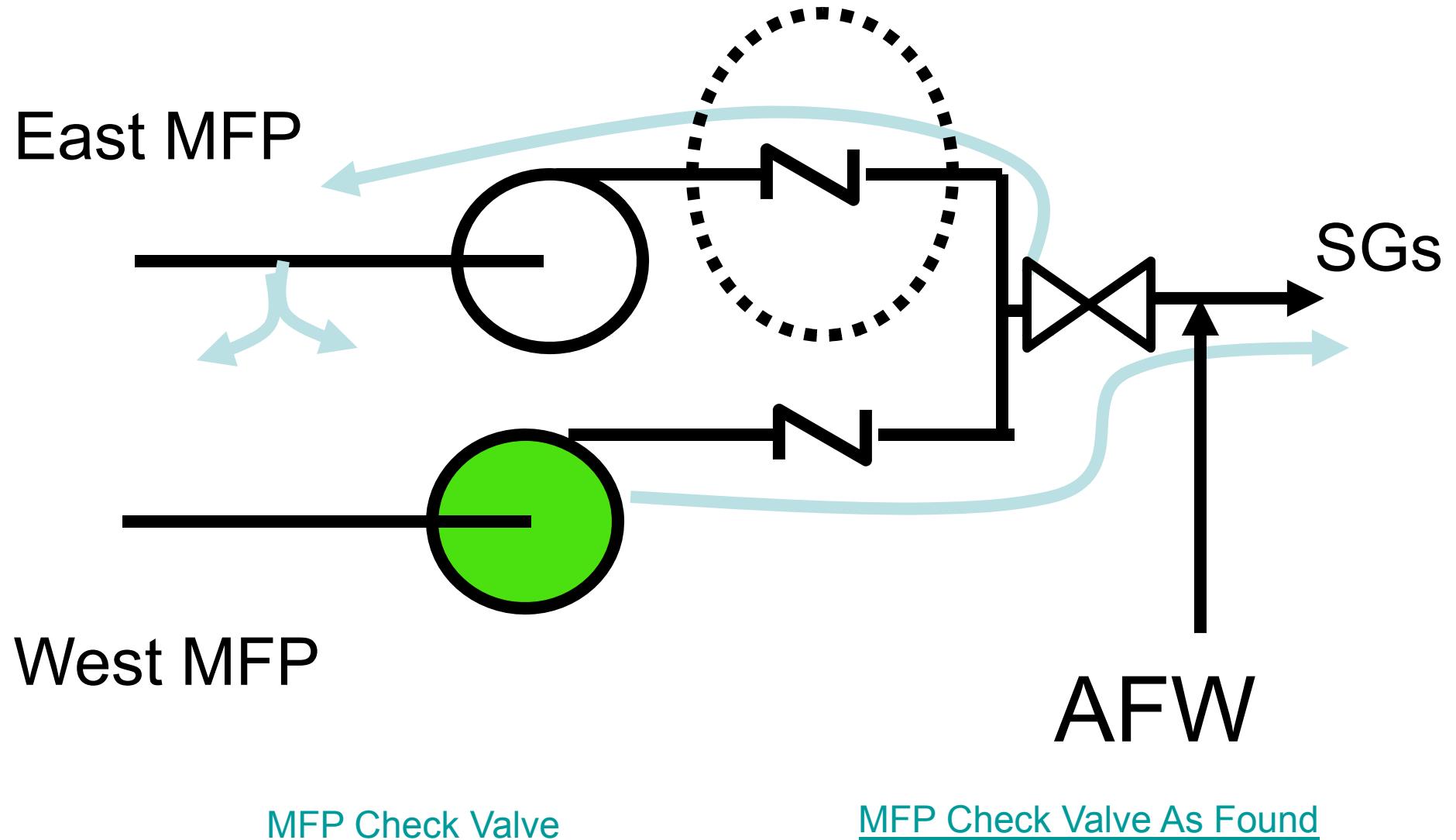
- 3) Limit AFW flow to avoid rapid refill of horizontal runs of FW piping.

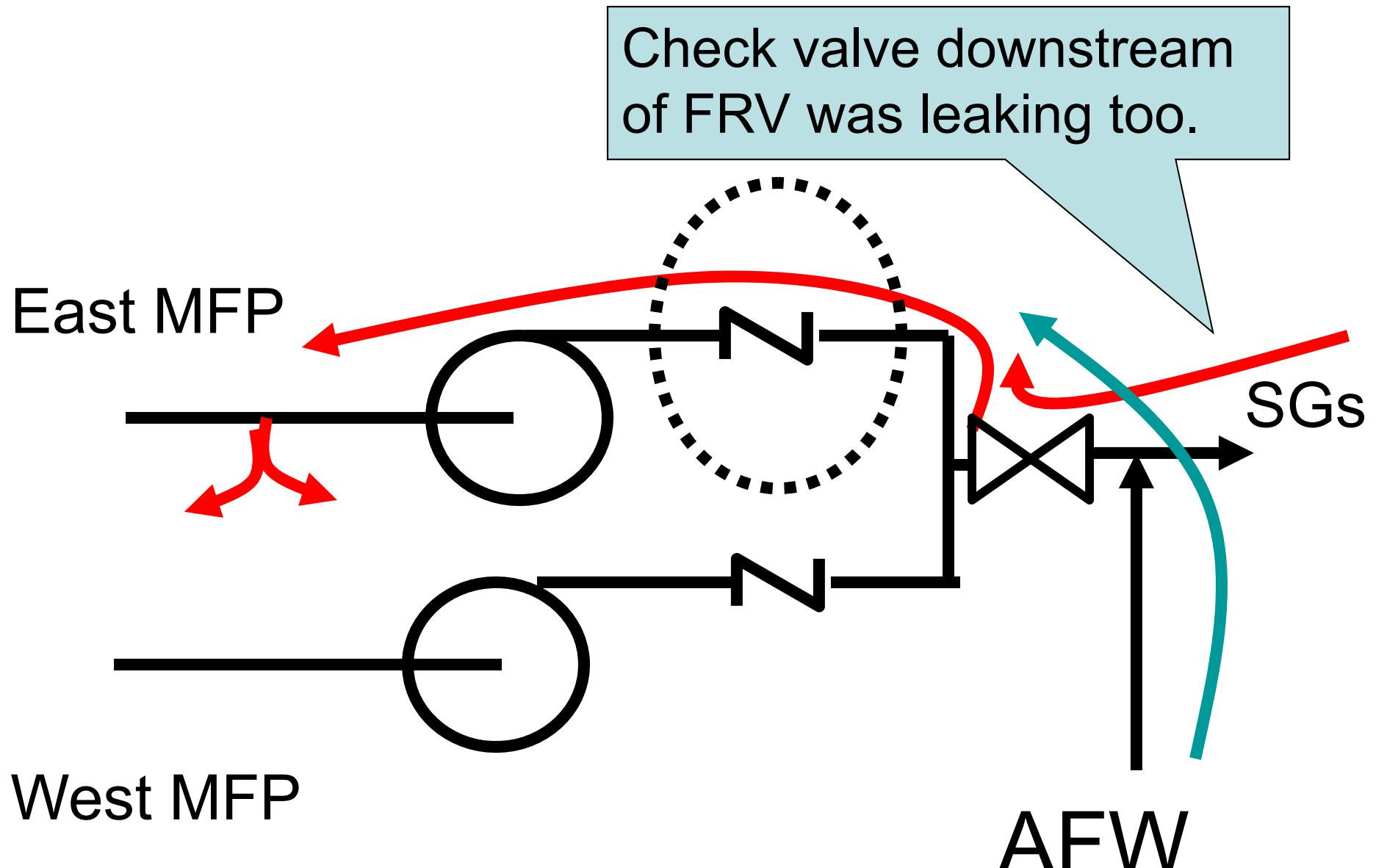


SONGS –1 Water Hammer (Sections 7.3.3 & 7.3.4)



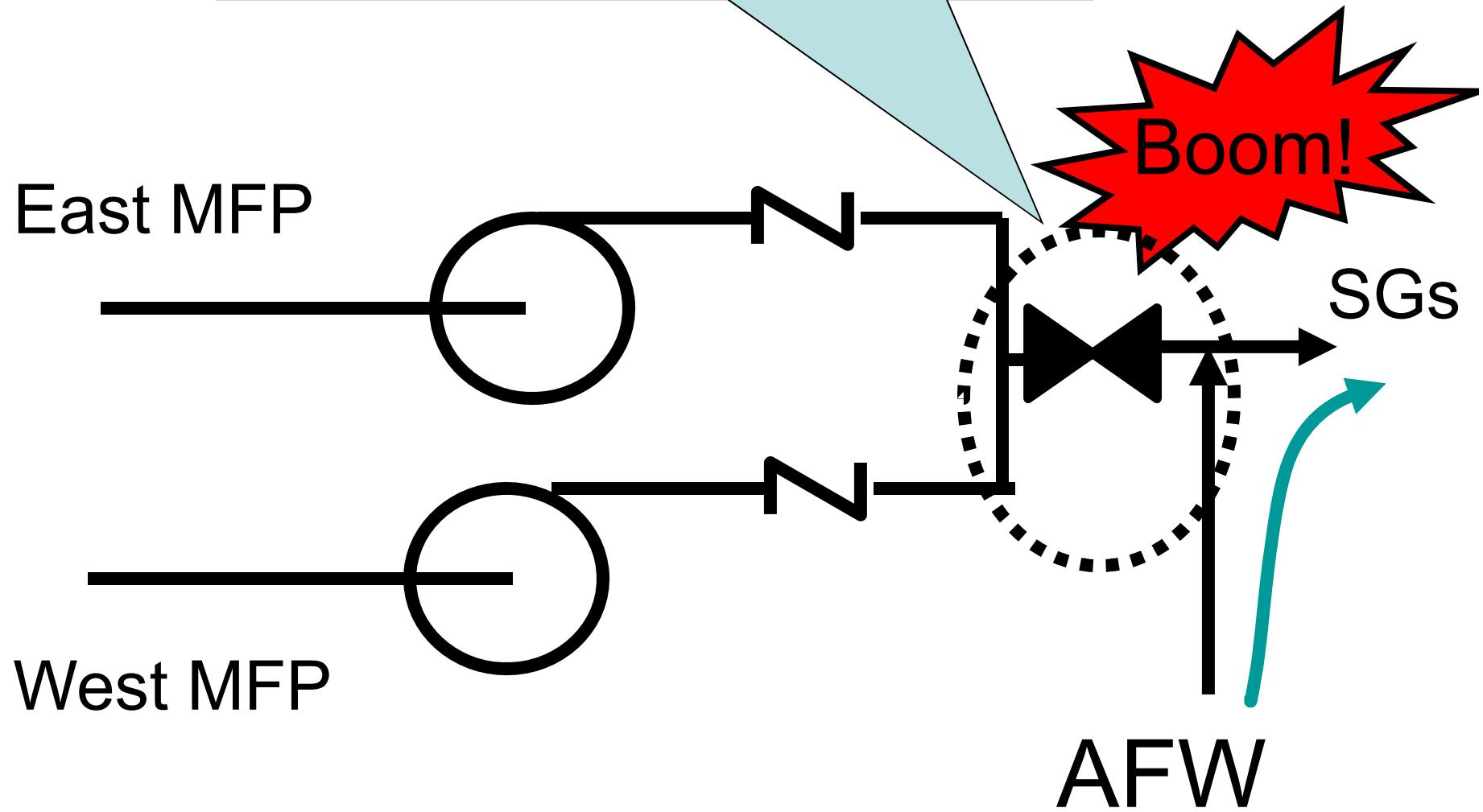
E-MFP lost due to Aux Transformer problem.





FRV Check Valve As Found

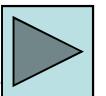
Operators closed FWIS valves.



Consequence / Damage

(Section 7.3.5)

- Cracked feedwater pipe.
- Several damaged pipe supports.
- Several damaged valves.



CAUSES

Failure of 5 safety related check valves.

Inadequate check valve testing.

Questions



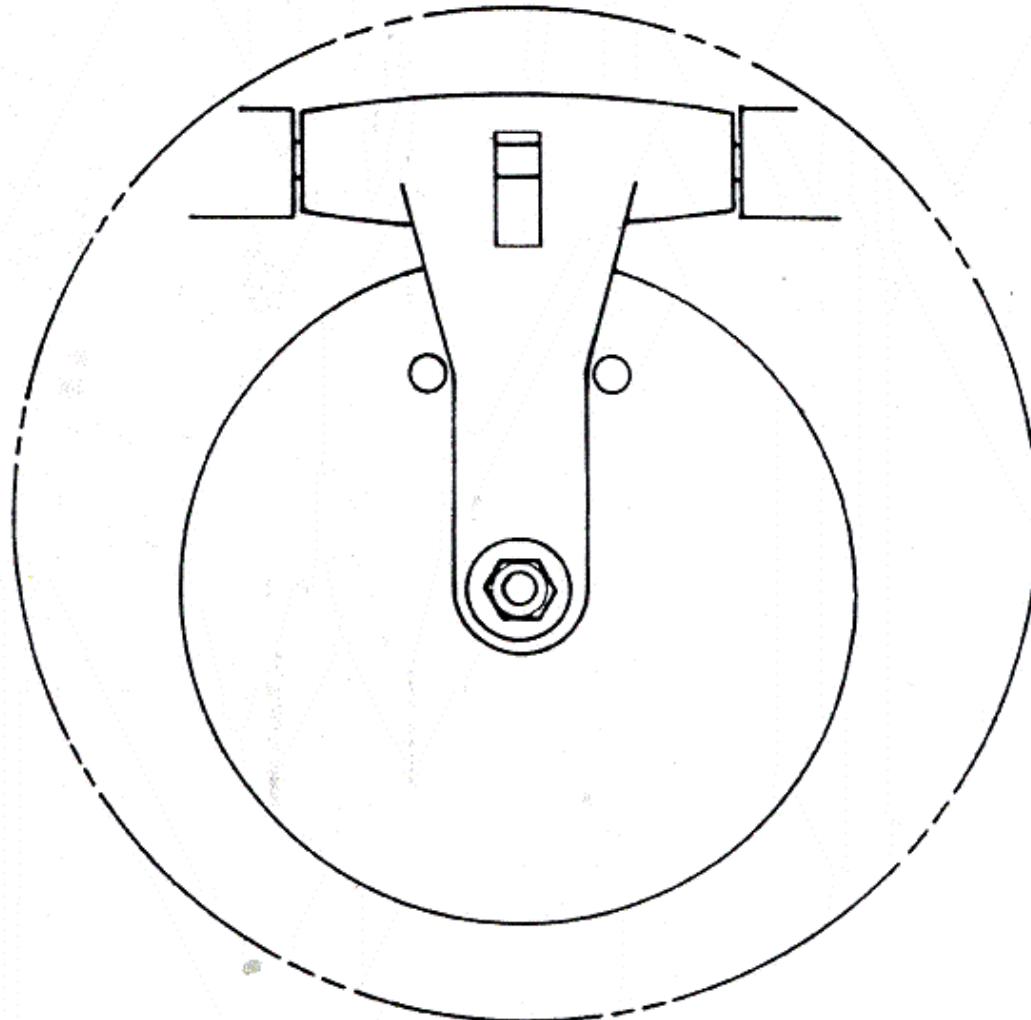
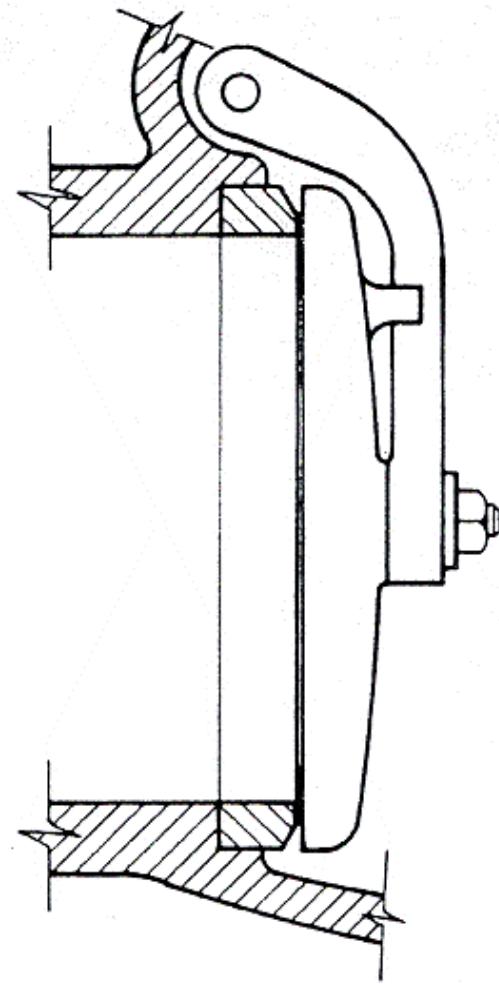
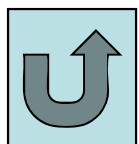


Fig. 7.3-13
MFP Discharge Check Valve Fully Assembled



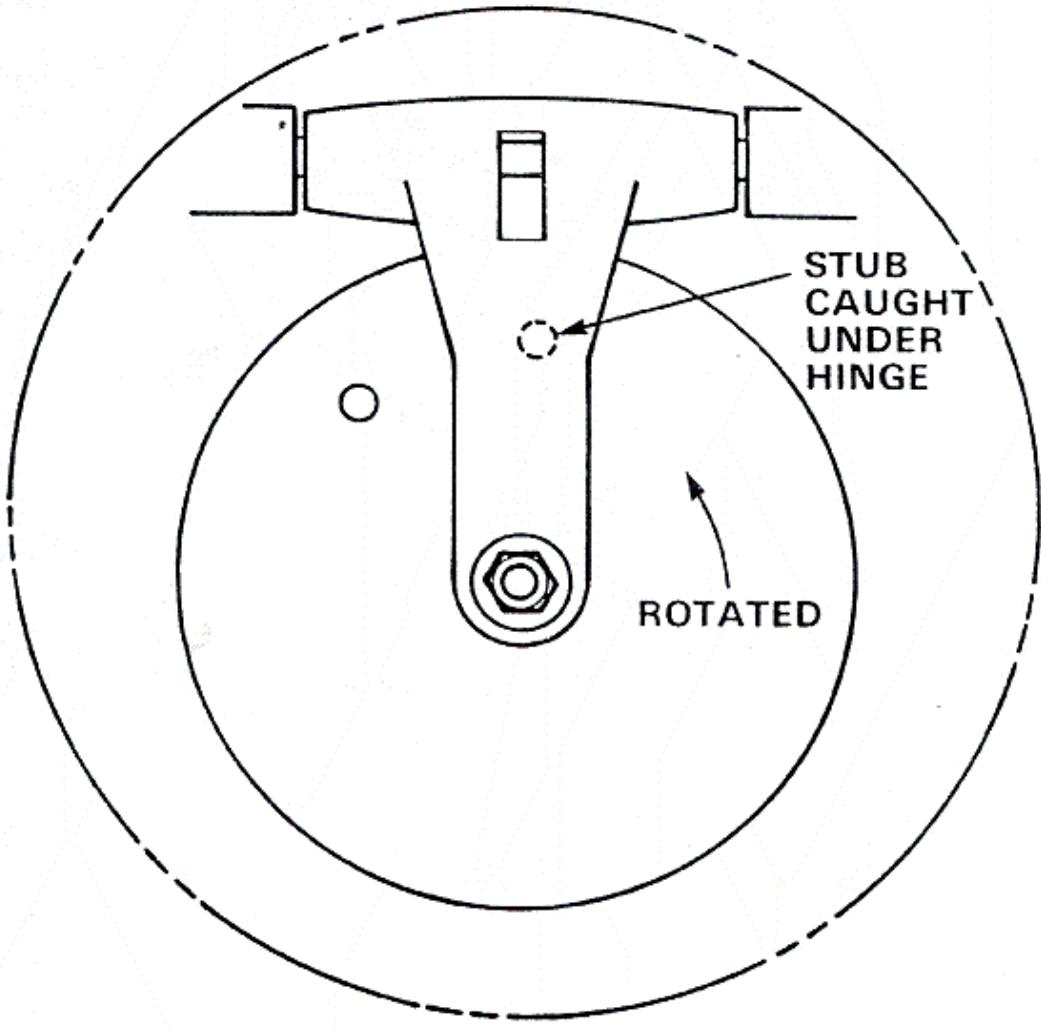
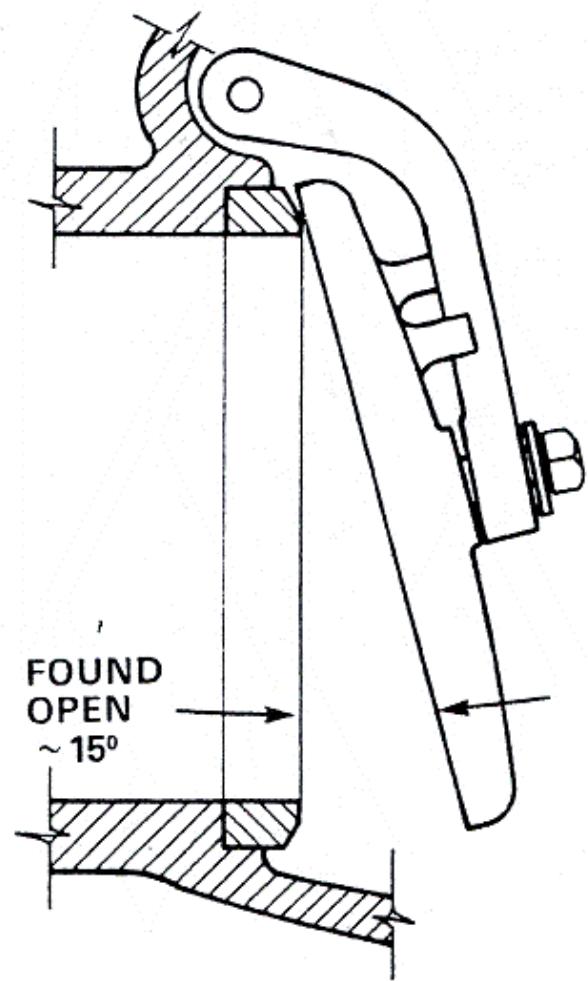


Fig. 7.3-13
MFP Discharge Check Valve As Found

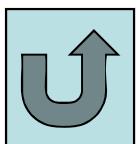


Fig. 7.3-12
Check Valve
Downstream
of FRV As
Found

